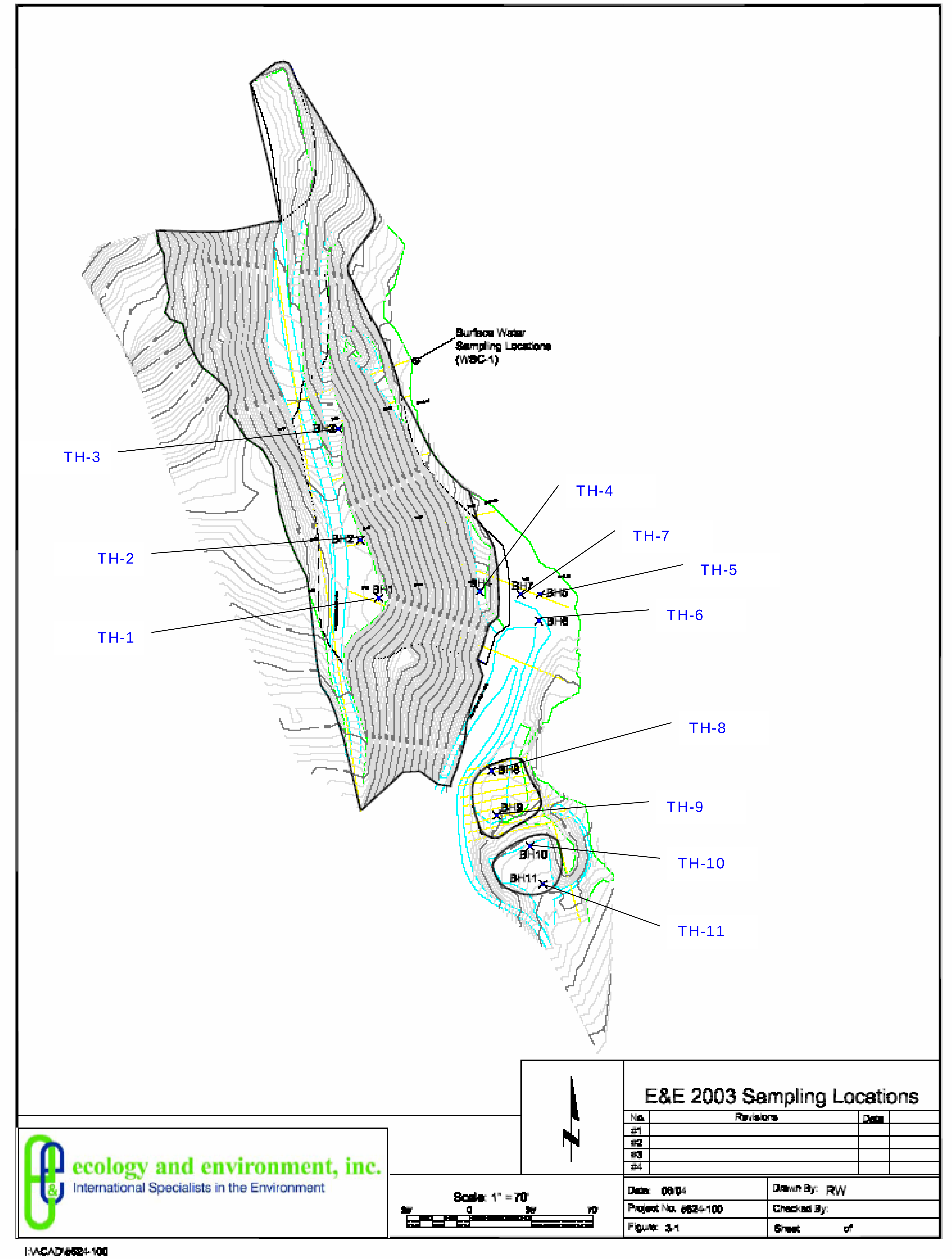
3 Source, Nature and Extent of Contamination

3.1 Location of Contaminated Materials

Waste shale, composed of spent (retorted) shale and raw shale fines (excluded from the retorting process) were disposed from the Plant Site at the top of the bench west of West Sharrard Gulch onto the steep slope descending to the gulch. The waste shale pile extends for approximately 900 feet along the floor of the gulch and reaches 150 feet in height at its highest point. The surface of the shale pile has a slope of about 1.4:1 and contains several areas of material sloughing. Industrial waste treatment ponds were formerly located at the base of the waste shale pile and to the south of the pile. The locations of the waste shale pile and impoundments are shown in Figure 3-1. Locations of Test Holes are also shown.

3.2 Volume of Contaminated Materials

Calculations of spent shale resulting from disposal of 425,000 tons of raw shale (NEESA 1985) yield a volume of about 393,500 cubic yards assuming a specific gravity of 1.08 tons per cubic yard. However, all recent estimates of the volume of spent shale remaining at the APF have been substantially lower. The volume of the spent shale pile was reported to be 178,000 cubic yards by Meade (Meade 1984). In 2004, Frontier Environmental, Inc. estimated a volume of 108,000 cubic yards based on a topographic survey of the shale pile and an estimate of the location of the natural hillside beneath the shale pile obtained from four geotechnical borings advanced through the shale pile (Frontier 2004). The United States Geological Survey (USGS) used linear interpolation, linear extrapolation, and grid volume methods to calculate shale pile volumes from geophysical data. Their estimates of the shale pile volume are 60,694, 60,977, and 74,419 cubic yards, respectively (USGS 2004).


Surface Water Sampling Locations (WSC-1)
TH-3
TH-2
TH-1
TH-4
TH-7
TH-5
TH-6
TH-8
TH-9
TH-10
TH-11
BH1
BH2
BH3
BH5
BH6
BH7
BH8
BH9
BH10
BH11
E&E 2003 Sampling Locations
ecology and environment, inc.
International Specialists in the Environment
Scale: 1" = 70'
Date: 08/04
Project No. 5624-100
Figure: 3-1
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Due to uncertainty about irregularities in the natural hillside where the waste oil shale was deposited, Frontier Environmental recommended using a volume of 130,000 cubic yards of material. To ensure that a conservative approach to quantity estimates is employed in this EE/CA, 130,000 cubic yards of waste shale will be used for cost estimating purposes. The amount of contaminated material within the Upper Process Pond, Overflow Pond, Relic Pond and sediments below the shale pile are estimated to be approximately 5,000 cubic yards (E&E 2004).

3.3 Physical and Chemical Attributes

3.3.1 Historical Site Characterization Activities

The APF has been the subject of numerous environmental investigations since the 1970s. Early investigations focused on a few select metal and organic compounds in surface and ground water contamination. Beginning in the late 1980s, investigations concentrated on characterizing site conditions with the objective of determining the presence, nature and extent of hazardous substances and the potential threat that they posed to human health and the environment. This section presents a summary of previous investigations including information about the principal physical and chemical attributes of the contaminants and the environmental media affected.

Ground Water

A number of reports since the 1970s have presented findings showing that ground water in West Sharrard Gulch have been impacted by operations at the APF. Among these, sampling and analysis of ground water in 1987 showed that concentrations of almost all priority pollutant metals, plus chloride and sulfate, were significantly elevated near the shale pile when compared to upgradient locations, and fell to near background levels at the downgradient boundary of the site (NEESA 1988). Organic contaminants were also found in ground water, including hydrocarbons and pyridines, the presence of which were attributed to *in-situ* combustion within the waste shale pile.

A site investigation study performed in 1998 analyzed samples from existing ground water monitoring wells in the immediate vicinity or down gradient from the spent shale pile. Results indicate that 12 inorganic compounds, numerous hydrocarbons, and pyridine isomers were detected in ground water at the APF at concentrations that exceed background levels and could be considered an observed release under the Hazardous Ranking System (HRS) criteria established under CERCLA (Dynamac 1998). The highest concentrations were observed just down gradient of the southern boundary of the spent shale pile. The study concluded that contaminant concentrations generally increased approaching to the southern boundary of the waste shale pile and decreased down gradient of the pile. An earlier analysis of ground water data indicated that inorganic concentrations were significantly higher in the vicinity of the shale pile and impoundments at either up gradient or down gradient locations. It was concluded that the source of the increased concentrations was the shale pile rather than the impoundments, based on comparisons of concentrations in the ground water and the ponds during 1974 to 1976 (NEESA 1985).

The Colorado Department of Public Health and Environment (CDPHE) conducted a Site Evaluation for the APF waste shale pile which included sampling of seven ground water monitoring wells (CDPHE 2000). The CDPHE concluded that iron, manganese, and sulfate are leaching from the spent shale pile into ground water, and are present in ground water at concentrations exceeding Colorado Primary or Secondary Ground Water Standards in one or more of the ground water monitoring wells they sampled. The CDPHE also noted that arsenic concentrations in ground water due to leaching from the pile did not exceed standards in effect in 2000, but could exceed proposed new standards. One result for arsenic was significantly higher than historic values and values at other wells, and was considered to be anomalous by CDPHE. The CDPHE concluded that inorganic constituents were found at concentrations above background water quality. Background water quality was obtained from a ground water monitoring well (OR-1) located upgradient of the waste shale pile. Table 3-1 presents the maximum concentrations of inorganics found in ground water by Dynamac 1998 and CDPHE 2000.

Surface Water

Numerous studies have laboratory analytical results of surface water samples from West Sharrard Creek. It is believed that releases of constituents to ground water from the spent shale pile and former process ponds are transmitted to the surface water of Sharrard Creek via ground water seeps (NEESA 1988). NEESA also concluded that "both surface water and shallow ground water are conducive to migration of potential contaminants southward from APF" (NEESA 1988). Within West Sharrard Creek, it is generally concluded that concentrations of numerous inorganic elements increase in surface water in the vicinity of the waste shale pile.

Dynamac collected five surface water samples along West Sharrard Creek as part of their 1998 site investigation. Selenium and zinc were found at concentrations exceeding the Colorado Water Quality Standards for the Lower Colorado River Basin. In addition, manganese was found to exceed the EPA Secondary Maximum Contaminant Level. Thallium, manganese, and potassium were detected at concentrations exceeding three times background. Organic analysis found concentrations of acetone, carbon disulfide, 1,2-dichloroethane, phthalate and siloxane that were considered typical of the oil shale production process (Dynamac 1998).

Most recently, CDPHE concluded that several inorganic elements were leaching (or eroding) into surface water from the waste shale pile, but only iron appeared to be at concentrations exceeding Colorado Water Quality Standards (CDPHE 2000). However, seeps into the gulch from the waste shale pile contained elevated concentrations of iron, manganese, and sulfate. CDPHE suggested that several elements are leaching from the

Table 3-1: Summary of Maximum Ground Water Concentrations, mg/L			
Analyte	Dynamac 1998	CDPHE 2000	Background[1]
Aluminum	81	NA	28
Antimony	ND	ND	ND
Arsenic	0.044	0.099	0.004
Boron	NA	0.84	0.35
Barium	0.49	0.48	0.24
Beryllium	0.0056	0.0018	ND
Cadmium	0.0089	0.006	ND
Calcium	460	NA	300
Chromium	0.13	0.0062	0.026
Cobalt	0.044	0.05	0.0098
Copper	0.094	0.071	0.018
Iron	76	54	19
Lead	0.056	0.09	0.022
Magnesium	430	NA	180
Manganese	2.7	5.94	0.34
Mercury	ND	0.00032	ND
Molybdenum	NA	0.14	ND
Nickel	0.11	0.068	0.019
Potassium	190	NA	29
Selenium	0.044	0.032	ND
Silver	ND	0.00025	ND
Sodium	1,100	768	370
Thallium	ND	ND	ND
Vanadium	0.21	0.088	0.071
Zinc	0.38	0.27	0.12

1. From Dynamac 1998 and CDPHE 2000 – both "background" samples collected from well APF-OR1.

NA = Not analyzed
ND = Not detected
mg/L = milligrams per liter

waste pile into the surface water. CDPHE also concluded that the concentrations of inorganic compounds in surface water appear to decline "considerably" with distance from the waste shale pile.

Eroded spent shale sediments have been observed in West Sharrard Creek all the way to the confluence with the Colorado River (CDPHE 2000). These observations probably represent the results of flash flood events and will continue to occur under current site conditions. A fire discovered in the shale pile in 1978 produced crude oil that seeped into West Sharrard Creek and ultimately produced enough oil to cause an oil slick on the

Colorado River. The oil was eventually diverted to a series of processing ponds located at the base of the pile (CDPHE 2000). Table 3-2 presents the maximum concentrations of inorganics found in surface water by Dynamac 1998 and CDPHE 2000, with comparisons to background samples obtained upstream of the waste shale pile.

Table 3-2: Summary of Surface Water Concentrations[1], mg/L

Analyte	Dynamac 1998	CDPHE 2000	Background[2]
Aluminum	0.11	NA	0.047
Antimony	ND	ND	ND
Arsenic	ND	0.002	ND
Boron	NA	0.33	NA
Barium	0.04	ND	0.036
Beryllium	ND	ND	ND
Cadmium	0.0021	ND	ND
Calcium	170	NA	100
Chromium	ND	ND	ND
Cobalt	0.005	ND	ND
Copper	ND	0.02	ND
Iron	0.042	1.26	0.024
Lead	ND	ND	ND
Magnesium	130	NA	68
Manganese	0.066	0.05	ND
Mercury	0.00005	ND	ND
Molybdenum	NA	0.1	NA
Nickel	ND	ND	ND
Potassium	41	NA	8.3
Selenium	0.017	0.01	0.019
Silver	ND	ND	NA
Sodium	1,800	215	220
Thallium	ND	ND	ND
Vanadium	ND	ND	ND
Zinc	0.086	0.05	0.041
Siloxane	0.054	ND	ND

1. From Dynamac 1998: filtered inorganics and unfiltered organics, highest value of five samples. From CDPHE 2000: (downstream from seep).
2. From Dynamac 1998 and CDPHE 2000: Dynamac collected a background surface water sample (APF-1SW) at a location upstream of APF-OR1. CDPHE collected a surface water sample (referred to as WOR1 in CDPHE's data table, and shown as ORW-1/5894 on CDPHE's map) at a location very near, but apparently slightly upstream from APF-1SW.

NA = Not analyzed
ND = Not detected
mg/L = milligrams per liter

Waste Shale and Soils

Dynamac conducted sampling and analysis of the shale pile and established that eight inorganic constituents (arsenic, barium, beryllium, chromium, copper, magnesium, sodium, and vanadium) were detected at concentrations exceeding three times background (Dynamac 1998). Arsenic and beryllium were observed in all three samples collected and concentrations of these metals exceeded the EPA generic ingestion Site Screening Levels (SSLs). Arsenic concentrations also exceeded the EPA generic ingestion SSL in the background sample. The presence of arsenic and beryllium contamination was attributed to the spent shale. The spent shale had no detectable volatile organic compounds (VOCs). Phthalate was detected at concentrations less than the practical quantitation limit, and high molecular weight hydrocarbons were also detected at concentrations in the 1.3 to 2.6 milligrams per kilogram (mg/kg) range. All of the spent shale samples were analyzed for Toxicity Characteristic Leaching Procedure (TCLP)., Corrosivity, Ignitability, and Reactivity Characteristics. The three waste shale samples did not contain hazardous constituents above toxicity characteristics that would qualify the material as a hazardous waste under the Resource Conservation and Recovery Act (RCRA).

Dynamac also conducted sampling and analysis of soils in the Upper Process Pond, Overflow Pond, and Relic Pond. Results were similar in character to the waste shale, with seven inorganics exceeding three times background, and arsenic and beryllium exceeding the EPA’s generic ingestions SSLs. Phthalate and high molecular weight hydrocarbons were also detected in soils from the impoundments.

CDPHE obtained laboratory data from six samples within the waste shale pile, and concluded that concentrations of aluminum, arsenic, boron, barium, chromium, cobalt, copper, iron, lithium, magnesium, manganese, molybdenum, sodium, nickel, lead, vanadium, and zinc were present at concentrations that are significantly above background soil concentrations (CDPHE 2000). CDPHE concluded that the concentrations of inorganic elements in the shale pile were not significantly variable at different horizontal locations across the pile. CDPHE also analyzed waste shale samples for organic contaminants, and concluded that the waste shale pile did not contain significant concentrations of organic contamination. CDPHE noted that earlier observations of organic compounds appeared to be localized at the base of the pile, and were likely generated by in-situ combustion within the pile. Table 3-3 presents the maximum concentrations of inorganics found in waste shale and soils by Dynamac 1998 and CDPHE 2000 compared to background samples collected at locations outside the limits of the waste shale pile.

Table 3-3: Summary of Maximum Soil/Shale Concentrations, mg/L			
Analyte	Dynamac 1998	CDPHE 2000	Background[1]
Aluminum	15,000	NA	6,300
Antimony	ND	0.8	0.05
Arsenic	47	37	6.7
Boron	NA	95	41.5
Barium	360	494	200
Beryllium	0.9	1.0	0.5
Cadmium	ND	ND	0.5
Calcium	100,000	NA	35,000
Chromium	26	32.5	16
Cobalt	8.6	9.0	5.5
Copper	41	41	12
Iron	17,000	24,000	13,000
Lead	23	26.5	15
Magnesium	35,000	40,800	16,100
Manganese	310	500	280
Mercury	ND	0.1	ND
Molybdenum	NA	13	ND
Nickel	21	22.5	14.5
Potassium	6,700	NA	1,500
Selenium	7.8	0.1	3.7
Silver	ND	ND	ND
Sodium	8,500	9,100	770
Thallium	1.1	0.6	0.4
Vanadium	88	108	37.5
Zinc	61	91	50

1. Highest reported value from Dynamac 1998 and CDPHE 2000 – Dynamac's background soil sample collected from well APF-1WAS-BG located above and east of West Sharrard Creek and north of the shale pile (refer to Dynamac's Figure 4). CDPHE collected a background soil sample (referred to as "Upstream Soil" in CDPHE's data table) at a location referred to as "at a point upgradient of the waste shale pile" on page 5 of the CDPHE report, but not further identified.

NA = Not analyzed
ND = Not detected
mg/L = milligrams per liter

Air

There are no current known contaminant releases to air at the site. The cohesive properties of the waste shale particles have been cited as a reason that the risk of windblown shale particles was not considered significant (ORNL 1994). Potential releases primarily include metals (arsenic) in dust emissions caused by road grading or oilfield construction activities. Concentrations of inorganic contaminants in the waste shale and soil are below the EPA generic inhalation SSLs (Dynamac 1998).

3.3.2 Sampling and Analysis Activities

Discussion of Sampling Protocol and Data Quality Objectives

Sampling and analysis activities undertaken, in part, to supplement the existing data for completion of the EE/CA included the following:

- Collecting geotechnical samples from four borings drilled into the shale pile;
- Collecting soil samples for environmental analysis during drilling of the four borings in the shale pile;
- Collecting soil samples from seven borings drilled into the impoundments at the base of the shale pile;
- Surveying the shale pile and conducting a buried metals survey to locate potential disposal areas for purposes of worker protection;
- Data from geophysical surveys by the USGS was correlated with geotechnical drilling and survey data to estimate the volume and characteristics of the shale pile; and
- Collecting surface water and seep samples.

The geotechnical and environmental samples of the processed oil shale pile and impoundments were collected on December 16 and 17, 2003. Spent shale waste material samples were collected at several vertical locations within the pile at four surface locations and drilling proceeded until 5 feet of native soils were penetrated. A total of 14 waste shale and five native soil samples were collected.

A buggy–mounted CME 45, auger drill capable of drilling the entire depth of the spent shale pile was used for all borings. A 4-inch diameter solid stem auger was used for collection of samples. A ring barrel sampler was used for collection of combined geotechnical and environmental samples. Intervals requiring only environmental analysis used a split-spoon sampler. Samples were collected at 10-foot intervals from 10 feet below ground to contact with native materials underlying the shale pile. Samples were collected either as splits from the ring barrel sampler or individually using a split-spoon sampler. Soil headspace was screened for VOCs using a photoionization detector (PID) and the selected aliquot was immediately placed into pre-cleaned laboratory certified sample jars, labeled and placed under chain-of-custody in ice filled coolers for overnight shipment to the laboratory. Sampling equipment was decontaminated using an Alconox™ -distilled water wash followed by triple rinsing with distilled water.

Two borings (TH-1 and TH-2) were performed at the top of the shale pile, as close to the outer edge as possible (so as to penetrate the maximum depth of shale prior to native soil). Two other borings were done lower in the shale pile, one from the former access road that trend northeast from the top of the pile (directly north of the "parking area" on top of the pile) and one from the bench near the base of the pile.

The samples from the waste shale pile and impoundments were analyzed for:

- Density
- Moisture content
- Gradation or sieve analysis
- Atterberg limits and Proctor analyses
- Direct shear
- VOCs and TCLP by Method 8260B
- Semi-VOCs and TCLP by Method 8270C
- Pesticides by Method 8081A
- Target Analyte List (TAL) and TCLP metals by Method 6010B
- Mercury in soil by Method 7471A
- TCLP Mercury by Method 7470A
- Polychlorinated Biphenyls (PCBs) by Method 8082

Geotechnical analyses were performed by Terracon's laboratory in Wheat Ridge, Colorado and environmental analyses were done by E&E's Analytical Services Center in Buffalo, New York.

The buried metals survey addressed the possibility that metallic materials (discarded equipment, etc.) could have been disposed of in the shale pile, which could impact worker safety while drilling boreholes (no buried metallic refuse was found). In addition, a flowline to a gas well is present underneath the roadway at the top of the shale pile, and the precise determine of its location was required.

Buried metals surveys were conducted at the Plant Site, Boneyard, Drum Draw, Town Site, Shale Pile and Impoundments, North Surface Disturbed Area, Mine Bench (in the area adjacent to the building foundation), and Water Plant (in the vicinity of the "oil storage area"). Indeed, a disposal area was located at the Boneyard, which is described in the SI report.

Boring logs indicate sample depths and types, penetration resistance measurements, and material descriptions. The boring logs also indicate the depths to the native ground surface ranged from 28 to 55 feet. The boring logs can be found in the Slope Stability Analysis Report in Appendix A. Seven borings were also drilled to depths ranging from 5 to 10 feet in the impoundments located just southeast of the spent oil shale pile in order to obtain samples of the subsoils for environmental analyses. A total of ten samples were collected from six of the borings. These borings were not sampled for geotechnical engineering parameters. Three borings were taken in the Relic pond and two borings were taken in each of the Upper Process Pond and Overflow Pond. Locations of the borings are shown in Figure 3-1. Ground water was not encountered in any of the borings in the waste shale or impoundments.

Surface water and seep samples were collected from West Sharrard Creek, in the vicinity of the metal haul cable crossing the creek (east of the former location of the retort), and at the seep just southeast of monitoring well AV-3A. The surface water and seep samples were analyzed for TAL metals by Method 6010B. The analyses were done by E&E's Analytical Services Center in Buffalo, New York.

The sampling and analysis was developed from the problem statements using the Data Quality Objectives (DQO) process, and was based on a conceptual site model developed from previous investigations. Sampling and analysis addressed three different problem statements: at the waste shale pile and associated soils, at the surface impoundments, and in surface and ground water. The elements of the DQO process resulted in quantitative standards being developed for surface water and soil based on: Colorado Surface Water and Groundwater Inorganic and Biological Standards, Colorado Soil Table Cleanup Value Standards, and EPA Ingestion Risk-Based Concentrations.

Analytical Results and Discussion

Complete analytical results are shown in Appendix B. No significant organic volatile or semi-VOCs concentrations were found in waste shale or native soil materials. Table 3-4 presents the maximum concentrations of metals in the waste shale and soils at the impoundments. Table 3-4 also presents the metals results from the surface water sample. The results are generally similar to historical site investigation results, with some slight variations as discussed below.

Table 3-4: Waste Shale, Soils and Surface Water Concentrations[1]

(E&E 2004)

Analyte	Waste Shale, mg/kg	Impoundments, mg/kg	Surface Water, µg/L[2]
Aluminum	19,500	21,900	ND
Antimony	ND	ND	ND
Arsenic	74.0	51.1	13.7
Barium	568	419 B	37.1
Beryllium	1.26	1.17	ND
Cadmium	0.375 J	0.366 JB	ND
Calcium	119,000	109,000	189,000
Chromium	33.5	33.9	ND
Cobalt	11.7	9.96	ND
Copper	199.0	52.7	ND
Iron	22,700	22,800	ND
Lead	42.2	27.4	ND

Table 3-4: Waste Shale, Soils and Surface Water Concentrations[1] (E&E 2004)			
Analyte	**Waste Shale, mg/kg**	**Impoundments, mg/kg**	**Surface Water, µg/L[2]**
Magnesium	43,200 B	39,400 B	136,000 B
Manganese	387 B	396 B	9.51 J
Mercury	0.0562	0.358	ND
Nickel	28.9	22.1	ND
Potassium	11,400	4,980	8,860 B
Selenium	4.88	4.54	52.9
Silver	0.494 J	0.537 J	ND
Sodium	23,400	8,730	347,000 B
Thallium	ND	ND	ND
Vanadium	113	87.7	16.6 J
Zinc	84.8	104	3.69 J

1. Reported results were obtained using EPA method SW6010B.
2. Surface water sample was collected from West Sharrard Creek at the location where the metal haul cable crosses the creek (approximately east from the former location of the retort).

ND = Not detected
J = Indicates value below reporting limit
B = Compound also detected in method blank

The following conclusions can be drawn from the analytical results.

- The reported concentrations of 23 TAL metals, volatile and semi-VOCs, and chlorinated pesticides and PCBs indicate that the waste shale is homogenous;
- Neither chlorinated pesticides nor PCBs were detected in boreholes drilled in the former impoundments;
- No TCLP volatile compounds were found in 29 waste shale and soil samples and no TCLP semi-volatiles were found in 28 waste shale samples;
- No TCLP metal concentration exceeds RCRA characteristic hazardous waste limits in the 28 waste shale samples;
- Arsenic concentrations in waste shale and native material beneath the waste shale exceed EPA SSLs and averaged 54.6 mg/kg;
- Beryllium concentrations in waste shale and native material beneath the waste shale exceed EPA SSLs and averaged 1.02 mg/kg;
- Aluminum, arsenic, calcium, copper, mercury, potassium, silver, sodium and vanadium were found at concentrations exceeding three times background, a result in concurrence with Dynamac 1998 and CDPHE 2000;
- Sodium, potassium, magnesium, aluminum, iron, chromium, and other metals are present at significantly higher concentrations in all samples, both waste shale and native than the Dynamac (1998) background and sediment samples;
- Arsenic and selenium concentrations appear similar to waste shale in native materials beneath the waste shale at some locations and significantly exceed the

concentration reported in the background sample reported by Dynamac (1998), but it is not known whether arsenic and selenium have leached from the waste shale into native material, or these results reflect the natural distribution of these elements; and

- Native material beneath the impoundments are not significantly elevated in arsenic or selenium.

Comparisons of the metals concentrations in waste shale, ground water and surface water to applicable standards is contained in the streamlined risk evaluation.

3.3.3 Geotechnical Properties

General Properties

Terracon completed laboratory testing and stability analysis of the waste shale pile at the APF as part of Frontier Environmental Services, Inc.'s topographic and geotechnical investigation report (Frontier 2004). Four test borings were drilled into the shale pile, with waste shale encountered to depths ranging from 28 to 55 feet.

The waste shale was considered very soft to hard in consistency for those portions that were cohesive. The portions that appeared non-cohesive were very loose to medium dense in relative density. Native bedrock materials were weathered to medium hard in hardness. The waste shale can be generally classified as lean clay (CL) or low plasticity silt (ML) with varying amounts of sand and gravel. The shale materials averaged 80 pounds per cubic foot, with moisture content averaging 17 percent (Frontier 2004). The internal angle of friction (phi-angle) derived from the direct shear strength tests was approximately 25 degrees.

One waste shale sample and one native soil sample were analyzed for particle size distribution. The results of these analyses are shown in Table 3-5.

Table 3-5: Particle Size Distribution of Waste Shale and Native Soils

Boring	Sample Type	% Passing by Weight				
		3"	#4	#10	#40	#200
3	Native soil – 60 ft	100	92	83	70	50
4	Waste shale – composite sample	100	73	62	46	33

Slope Stability

Based on testing results for direct shear, the approximate configuration of the existing waste shale slope, and the estimated bedrock surface as interpolated between borings, Terracon performed slope stability analyses. Based on these analyses, the minimum factor of safety of the waste shale slope ranged between 0.6 and 0.9. Terracon advised that a factor of safety less than 1.0 indicates that failure of the slope is likely to occur.

Factors of safety between 1.3 and 1.5 are generally considered to be the minimum for long-term stability. A slope configuration of 2:1 (horizontal: vertical) is required to provide a 1.3 safety factor. The current configuration of the slope is 1.4:1. The complete results of the geotechnical tests are in the Slope Stability Analyses report included in Appendix A.

3.4 Targets Potentially Affected by the Site

3.4.1 Ground Water

Municipal Wells

There are no municipal wells in Rifle, Rulison, or Parachute; these communities derive their drinking water entirely from surface water. Battlement Mesa has a wellfield near the Battlement Mesa-Parachute Bridge, approximately 10 miles west of the APF that is used only as an emergency water supply, supplementing surface water. The wells are completed in shallow alluvium and are considered drawing from "ground water under the influence of surface water" (personal communication with Doug Ayers, Battlement Mesa Metropolitan District 2004).

Private Wells

There are five permitted domestic water wells within 3 miles of the APF Plant Site that are potential targets of ground water contamination. These wells are adjacent to or within 0.3 miles of the Colorado River, and are perforated at depths ranging from 48 to 270 feet. Those nearest the Colorado River are presumably drawing from alluvium; those higher up on the valley floor may be drawing from bedrock. There is a home recently completed directly north of I-70 and southwest of the Williams water evaporation facility, or 1.5 miles southwest of the shale pile. There is no information available about installation of water well at this home site.

3.4.2 Surface Water

Municipal and Private Users

The town of Parachute (population 1,006 in 2002) derives most of its potable water from a spring on Battlement Mesa south of the Colorado River. During summer months, supplemental water is drawn from the Colorado River. Battlement Mesa (population 3,497 in 2000) has a similar situation. The town of Rifle is upstream from the confluence of West Sharrard Creek and the Colorado River; Rifle derives its water from the Colorado River and Beaver Creek on the south side of the Colorado River. There are several houses south of the Colorado River within a 4-mile radius of the Plant Site. One is along the valley floor; several are on a bench significantly above the valley floor. Some residents in Rulison (and presumably those in similar settings in the valley) gather water in cisterns from springs and from the Colorado River. Private land is present within and adjacent to the APF and development of these lands could occur in the future.

Ecological Targets

Releases to surface water from the waste shale pile and impoundments would likely pose the most direct risk to ecological receptors in the intermittent West Sharrard Creek. Various benthic invertebrates could be receptors of releases, as well as deer and elk that might drink water from the creek when it is flowing. Other mammals and birds could also be incidental consumers of water from the creek when flowing. Seven sensitive fish species are present within the Colorado River in this vicinity. A variety of shore birds, water birds, and raptors—some of which are sensitive will eat the sediments, invertebrates, and vertebrates that live in the Colorado River and thus are also potential receptors.

3.4.3 Soil and Air

Human Targets

There are no residents on site or workers in permanent facilities. Oilfield workers frequently transit the site to service the wells and gathering lines present throughout the APF. The site is used periodically for recreation. The project team noted that hunters were present on site during the hunting season. There is no evidence of significant off-road vehicle activity at the site.

Workers present within 4 miles of the site include those of Cimarron Oil and Gas Processing Equipment, Inc., which currently occupies the former Paraho Development building, approximately ½ mile south of the waste shale pile. Three to four workers are present in this building on a regular basis. The West Garfield Landfill is approximately ¾ mile east of the former Town Site and has 14 people present on a regular basis. The Williams Energy water evaporation facility south of the APF (about 1 mile south of the waste shale pile) and the Rulison Compressor Station do not have workers present on a continual basis. Oilfield workers also are present throughout the area to service the wells and associated facilities. Four drilling rigs will be continuously drilling wells in Sharrard Park for the next year, which will employ about 40 people (personal communication with Alan Kraus, 2004).

The nearest home is located 1.1 miles east of the site. It is downwind relative to the prevailing westerly winds. The next closest residence, when completed, will be the home currently under construction about 1.5 miles southwest of the Plant Site. There are four homes about 3.5 miles southwest of the APF.

Ecological Targets

Sensitive environments on site or within 4 miles of the APF includes habitat of several sensitive plants species, including the federally listed DeBeque milkvetch. Due to the inhospitable soil conditions of the shale pile and former impoundments, it is unlikely that any of the sensitive plants occur on these contaminated materials. However, windblown dust from the shale pile and impoundments could be deposited on the foliar surfaces or other above-ground parts of these plants, resulting in direct uptake into plant tissue from aerial deposition. Uptake can also occur through the roots as a result of transport into the soil from deposited windblown dust or by runoff from the shale pile onto the soil.

These soil-to-plant pathways can also affect plants other than the sensitive species. Some of these other species may be affected by uptake of contaminants from roots or foliage and hence would tend to become under-represented in exposed plant communities. However, most plant species are likely to tolerate aerial deposition but may accumulate the contaminants in their above-ground parts. Herbivores, including deer, elk, myriad smaller species, and livestock, may then be exposed to these contaminants by ingestion.

Sensitive wildlife habitats onsite or within 4 miles include critical mule deer winter range, riparian corridors along ephemeral drainages, the Colorado River riparian corridor, the Colorado River aquatic habitat, Fravert Reservoir, and any seasonal pools used for breeding by amphibians or as wildlife/livestock watering holes.

In addition to direct exposure by ingestion of plant material or surface water, site contaminants may also enter the food web by other means. For example, burrowing animals (including most small mammal species that provide an important prey base for many predators) may uptake contaminants by incidental ingestion of soil, inhalation of particulate-born or gaseous contaminants, or through the skin (dermal) exposure, as well as ingestion of plants or water. Herbivores may also ingest soil incidentally during consumption of plant foods, especially when grazing on low-growing or sparse vegetation.